METHOD AND APPARATUS FOR EFFICIENT SELECTION AND ACQUISITION OF A WIRELESS COMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

5   [0001] The present invention relates generally to wireless communications and, in particular, to a method and apparatus for efficiently selecting and acquiring a preferred wireless communications system.

Description of the Related Art

[0002] A mobile device will often have access to more than one wireless
10   communications system in its geographic region. The quality of the wireless services available to the mobile device may vary from system to system depending on the equipment used by each system, the features of the mobile device, the distance between the mobile device and local base stations, physical obstructions such as buildings and hills, and the volume of communications traffic on each system. The
15   wireless communications systems may also support different multiple-access wireless communications protocols such as code division multiple access (CDMA), wideband CDMA (WCDMA), Advanced Mobile Phone Service (AMPS), Global System for Mobile communications (GSM), General Packet Radio Services (GPRS) or High Data Rate (HDR) technology (e.g., 1xEV technology). In addition, the fees charged to a
20   user of the mobile device may vary depending on the time of day, the duration of the connection with the wireless communications system and whether the mobile device is listed as a subscriber of the wireless communications system.

[0003] To assist with the selection of a desirable wireless communications system, conventional mobile devices store data describing known systems in a preferred
25   roaming list (PRL). The PRL typically includes a systems table which stores a system identifier (SID) and a network identifier (NID) for each known wireless communications system, and an acquisition table which stores acquisition parameters including band, frequency and mode, for the known wireless communications systems. Within the systems table, the wireless communications systems may be
30   grouped by geographic region and sorted from the most desirable to the least desirable

system in each region. The most desirable system in a particular geographic region is typically a subscriber system, but may also be a roaming system that offers the mobile device a favorable combination of low cost and high quality of service. Roaming systems offer wireless services to non-subscriber mobile devices, usually at a much

5   higher fee than subscription services, and may be desirable when the mobile device enters a geographic region that is outside the coverage area of the mobile device's subscription service, when the subscription services are blocked or otherwise unavailable, or when the subscription services are only available at an unacceptably low level of quality.

10   [0004] During a mobile device's power-up sequence, attempts are made to acquire and register with the most desirable wireless communications system that is available to the mobile device in its current geographic region. In one approach, the mobile device identifies its current geographic region and then steps through the entries in the systems table, from the most desirable system in the identified geographic region to

15   the least desirable system in the identified geographic region, until a system acquisition and registration attempt is successful. The mobile device may also attempt to acquire and register with a new wireless communications system during operation. For example, the connection between the mobile device and a current wireless communications system may be lost, requiring the acquisition of a new

20   system by the mobile device. In addition, the wireless communications systems that are available to the mobile device may change as the position of the mobile device and its surrounding environment changes. To provide the user of the mobile device with the best combination of high quality and low cost, many mobile devices periodically attempt to acquire and register with a wireless communications system

25   that is more desirable than the current wireless communications system used by the mobile device. The mobile device typically searches the systems table for wireless communications systems in its geographic region that are more desirable than the current system used by the mobile device. If more desirable systems are found in the systems table, the mobile device will switch away from the current communications

30   channel and attempt to acquire and register with one of the more desirable systems.

[0005] A system acquisition sequence, such as the system acquisition sequences described above, will often include a series of failed attempts to acquire a signal and

register with the corresponding wireless communications system, followed by a single successful system acquisition and registration. These failed registration/acquisition attempts are common, time consuming (e.g., each failed attempt may take up to 20 seconds) and may be caused by a variety of factors. For example, the mobile device

5   may be unable to detect a pilot signal transmitted from a system base station if the pilot signal is blocked or weakened by physical obstructions, or if the mobile device is outside the base station's coverage area. Registration with the system may fail if the mobile device and the system use incompatible protocol revisions and hardware, or if system otherwise rejects the registration attempt of the mobile device.

10   [0006] In view of the above, there is a need in the art for a method and apparatus for efficiently selecting and acquiring a wireless communications system.

SUMMARY OF THE INVENTION

[0007] The present invention is a method and apparatus for efficiently selecting and

15   acquiring a wireless communications system. In a preferred embodiment, a mobile station is adapted to avoid unusable wireless communications systems during system acquisition. The mobile station includes processing circuitry and a memory storing a preferred roaming list and system avoidance data. The system avoidance data identifies unusable systems and includes corresponding avoidance criteria. The

20   processing circuitry is preferably adapted to select a system from the preferred roaming list in accordance with a predetermined system acquisition procedure. The selected system is skipped if corresponding avoidance criteria is satisfied. If the selected system is usable, the mobile station may attempt to acquire and register with the selected system. The processing circuitry is further adapted to add systems to the

25   system avoidance data in response to a communications failure, and remove systems from the system avoidance data when corresponding avoidance criteria is no longer satisfied.

[0008] The mobile station preferably includes processing circuitry, a memory, a communications transceiver and an antenna. The processing circuitry includes a

30   control processor for controlling the operation of the mobile station, a signal processor, a searcher, a system determination unit and a clock. The memory stores a preferred roaming list (PRL) that includes a list of wireless communications systems

that are used by the mobile station during attempts to acquire and register with a wireless communications system. The PRL preferably includes a systems table that stores a list of system identifiers and corresponding desirability and geographic information, and an acquisition table that stores a list of acquisition parameters that

5 are necessary for the acquisition of the wireless communications systems listed in the systems table. In a preferred embodiment, the PRL is maintained by an external source, such as the mobile station's wireless service provider.

[0009] The processing circuitry is adapted to create and maintain a list of unusable systems that is stored in the memory and includes a plurality of system identifiers and

10 corresponding avoidance criterion. Each system identifier identifies one or more wireless communications systems and may include a SID/NID combination, a frequency or other identifier. A wireless communications system is considered unusable if it is identified by a system identifier in the list of unusable systems and the corresponding avoidance criterion is satisfied. The processing circuitry is also

15 adapted to detect a communications failure with a currently selected wireless communications system and add a record to the list of unusable systems including an identifier of the failed system and corresponding avoidance criterion that is based on the detected communications failure.

[0010] In a preferred embodiment, the avoidance criterion includes an avoidance time

20 that is equal to a current time plus an avoidance duration. The avoidance duration may be found in a lookup table that includes an entry for each of a plurality of communications failures and corresponding avoidance durations. When a system acquisition/registration attempt fails, the mobile station identifies the cause of the failure and locates the corresponding avoidance duration in the lookup table. The

25 corresponding avoidance duration is then added to a current time to produce an avoidance time for the failed system. The avoidance time identifies a time period during which the corresponding wireless communications system is unusable. After the avoidance time expires, the system becomes usable and may be removed from the list of unusable systems.

30 [0011] In operation, the mobile station attempts to acquire a wireless communications system in accordance with a predetermined system acquisition procedure. As each system is selected from the PRL, the mobile station searches for the selected system

in the list of unusable systems and, if found, analyzes the corresponding avoidance criterion to determine whether the selected system is unusable. If the selected system is unusable, it will be avoided by the mobile station and the next system is selected from the PRL in accordance with the predetermined system acquisition procedure. If

5   a usable system is selected, an attempt is made to acquire the signal and register with the selected system. After a successful system acquisition/registration, the mobile station may use the system for future wireless communications services. If the acquisition/registration attempt is unsuccessful, then the selected wireless communications system is added to the list of unusable systems along with

10   corresponding avoidance criterion.

[0012] A more complete understanding of the Method and Apparatus for Efficient Selection and Acquisition of a Wireless Communications Systems will be afforded to those skilled in the art, as well as a realization of additional advantages and objects thereof, by a consideration of the following detailed description of preferred

15   embodiments. Reference will be made to the appended sheets of drawings, which will first be described briefly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The features, objects, and advantages of the present invention will become

20   more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[0014] Fig. 1 illustrates a preferred embodiment of the present invention;

[0015] Fig. 2 is a mobile station in accordance with a preferred embodiment of the

25   present invention;

[0016] Fig. 3a is a systems table in accordance with a preferred embodiment of the present invention;

[0017] Fig. 3b is an acquisition table in accordance with a preferred embodiment of the present invention;

30   [0018] Fig. 3c is an avoidance data table in accordance with a preferred embodiment of the present invention;

[0019] Fig. 3d illustrates an alternative embodiment of an avoidance data table;

[0020] Fig. 4 is a flow diagram illustrating a preferred system acquisition procedure; and

[0021] Fig. 5 illustrates an avoidance duration lookup table in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0022] A preferred embodiment of the present invention is illustrated in Figs. 1-5. Referring to Fig. 1, a mobile station 2 operates in a geographic region 4 that is serviced by at least one base station 6. Each base station 6 is connected to a network 8, which is part of a larger wireless communications system that supports at least one multiple-access wireless communications protocol, such as code division multiple access (CDMA), wideband CDMA (WCDMA), Advanced Mobile Phone Service (AMPS), Global System for Mobile communications (GSM), General Packet Radio Services (GPRS) or High Data Rate (HDR) technology (e.g., 1xEV technology). The mobile station 2 may be any wireless device, whether stationary or mobile, that is adapted for wireless communications with at least one base station 6, such as a cellular telephone, pager, personal digital assistant (PDA), vehicle navigation system or portable computer.

[0023] The mobile station 2 preferably includes a preferred roaming list (PRL) 10 and system avoidance data 12. The PRL 10 is stored in a nonvolatile memory of the mobile station 2 and includes a list of wireless communications systems and corresponding acquisition parameters that are used by the mobile station 2 during attempts to acquire and register with a wireless communications system. In a preferred embodiment, the PRL 10 is updated by the mobile station's wireless service provider and includes a list of wireless communications systems that are available to the mobile station 2 through its wireless service provider or other wireless service providers that have agreed to provide roaming services to the mobile station 2. The system avoidance data 12 is maintained by the mobile station 2 and includes a list of wireless communications systems and corresponding avoidance criterion. In a preferred embodiment, each wireless communications system listed in the avoidance data 12 is unusable and will be avoided by the mobile station 2 as long as the corresponding avoidance criterion is satisfied.

[0024] In operation, the mobile station 2 attempts to acquire a wireless communications system in accordance with a predetermined system acquisition procedure. The system acquisition procedure preferably includes selecting wireless communications systems in an order of desirability in the mobile station's current

5   geographic region 4 from the PRL 10. As each system is selected, the mobile station 2 searches for the selected system in the avoidance data 12 and, if found, analyzes the corresponding avoidance criterion to determine whether the selected system is unusable. If the selected system is unusable, it will be avoided by the mobile station 2 and the next system is selected from the PRL 10 in accordance with the system

10   acquisition procedure. If a usable system is selected, an attempt is made to acquire a corresponding signal and register with the selected system. After a successful acquisition/registration, the mobile station 2 may use the selected system for future wireless communications services. If the acquisition/registration attempt is unsuccessful, then the selected wireless communications system is added to the

15   avoidance data 12 along with corresponding avoidance criterion.

[0025] Referring to Fig. 2, a preferred embodiment of the mobile station 2 will now be described. The mobile station 2 includes processing circuitry 80, a memory 82, a communications transceiver 84 and an antenna 86. The processing circuitry 80 preferably includes a control processor 90 for controlling the operation of the mobile

20   station 2, a signal processor 92, a searcher 94, a system determination unit 96 and a clock 98. The memory 82 preferably includes both volatile and nonvolatile random access memories that store a preferred roaming list, including a systems table 100 and an acquisition table 102, and avoidance data 104. The memory 82 may also store one or more lookup tables 106.

25   [0026] The searcher 94 is adapted to identify valid signals, such as pilot signals, synchronization channels and paging channels received by the transceiver 84 through the antenna 86. The design and implementation of searcher hardware for CDMA acquisition is described in U.S. Patent No. 5,109,390, entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the

30   assignee of the present invention, and is incorporated herein by reference. The system determination unit 96 is adapted to select one or more wireless communications systems from the systems table 100 and retrieve corresponding acquisition parameters

from the acquisition table 102. The system determination unit 96 is further adapted to forward the acquisition parameters to the searcher 94, which attempts to acquire one the selected systems. In an alternative embodiment, the system determination unit 96 determines whether the current wireless communications system is the most desirable

5   system in the mobile device's current geographic region and, when more desirable systems are available, initiates attempts by the mobile station 2 to acquire a more desirable system. A method and apparatus for performing preferred system selection in a mobile station that is capable of operation in a plurality of geographic regions is disclosed in U.S. Patent No. 6,085,085, entitled "METHOD AND APPARATUS

10   FOR PERFORMING PREFERRED SYSTEM SELECTION," assigned to assignee, and is incorporated herein by reference.

[0027] Referring to Figs. 2 and 3a, a preferred embodiment of the systems table 100 will now be described. The systems table 100 includes a list of wireless communications systems that the mobile station 2 uses during attempts to acquire and

15   register with a wireless communications system. As illustrated, each record in the systems table 100 preferably includes a system identifier (SID), a network identifier (NID), an indication of whether the system is preferred or negative (P/N), an identifier of the geographic region (Region) and a pointer (AT Pointer) to a record in the acquisition table 102. Each wireless communications system listed in the systems

20   table 100 is identified through a unique SID/NID pair and is designated as either a preferred system that may be used by the module device 2 during roaming, or a negative system that should not be used by the mobile device 2 during roaming. In alternative embodiments, the wireless communications systems listed in the systems table 100 may be identified using other system identifiers, such as an Internet Protocol

25   Version 6 (IPV6) address or a Public Land Mobile Network (PLMN) identifier. The wireless communications systems are preferably grouped by geographic region and stored in the systems table 100 in sorted order from the most desirable system to the least desirable system in each region. The desirability of each system may be determined using criteria such as the cost of using the system, the quality of the

30   communications service offered by the system, protocol used by the system, support for unique features and whether the mobile station 2 is a subscriber of the wireless communications system. In alternative embodiments, the systems table 100 may

include other information such as a desirability rating (e.g., a numerical score) for each system and acquisition parameters.

[0028] Referring to Fig. 3b, a preferred embodiment of the acquisition table 102 will now be described. The acquisition table 102 includes a list of parameters that are necessary for the acquisition of the wireless communications systems listed in the systems table 100. As illustrated, each record in the acquisition table 102 preferably includes a mode, a band and a frequency. It will be appreciated, however, that other system acquisition parameters may be used. The systems table 100 and the acquisition table 102 are preferably stored in a nonvolatile memory and updated periodically by an external source, such as the mobile station's wireless service provider, through downloads across a wireless connection or through another data transfer method.

[0029] A preferred embodiment of the avoidance data 104 will now be described with reference to Figs. 2 and 3c. The avoidance data 104 is stored as a table in either a volatile or nonvolatile memory of the mobile station 2. Each entry in the avoidance data 104 includes an identifier of one or more wireless communications systems, such as a unique SID/NID pair or a frequency, and corresponding avoidance criterion, such as an Avoidance_Time. In a preferred embodiment, the Avoidance_Time is the time, as measured by clock 98, after which it is permissible to attempt acquisition of the corresponding wireless communications systems. In a first alternative embodiment, illustrated in Fig. 3d, each entry in an avoidance data table 106 includes a mode, band and frequency to be avoided during future system acquisition attempts, and an Avoidance_Time that defines a time period during which the mode, band and frequency should be avoided. In a second alternative embodiment, the avoidance data may include historical information, such as an identification of the most recent acquisition/registration failure for each wireless communications system.

[0030] A preferred system acquisition sequence for the mobile station 2 will now be described with reference to Fig. 2 and the flow diagram of Fig. 4. The illustrated system acquisition sequence is preferably performed by the processing circuitry 80 before an attempt is made to acquire and register with a wireless communications system. In Step 150, the mobile station 2 selects a system from the systems table 100 in accordance with a predetermined system acquisition sequence. In a preferred

embodiment, the most desirable system in the mobile station's current geographic region is selected from the preferred roaming list. In Step 160, the mobile station 2 searches for the selected system in the avoidance data 104 and, if found, analyzes the corresponding avoidance criterion to determine whether the selected system is

5   unusable.   In a preferred embodiment, the avoidance criterion includes an Avoidance_Time, which is compared to a current time as measured by clock 98. If the Avoidance_Time is greater than the current time then the selected system is unusable and should be avoided, and control returns to Step 150 where the next most desirable system is selected from the preferred roaming list.

10 [0031] If the selected system is not found in the avoidance data 104, or if the selected system is found in the avoidance data 104 and the Avoidance_Time is less than the current time, then the selected system is usable and control passes to Step 170. In a preferred embodiment, the processing circuitry 80 removes usable systems from the avoidance data 104. In Step 170, an attempt is made to acquire and register with the

15 selected system. If the system acquisition/registration attempt is successful (Step 180), the mobile station 2 uses the selected system for future wireless communications services. If the acquisition/registration attempt is unsuccessful then the selected system is added to the avoidance data 104 along with a corresponding Avoidance_Time, in Step 190. The Avoidance_Time is preferably calculated by

20 adding an Avoidance_Duration to a current time as measured by clock 98. After the avoidance data 104 is updated, control returns to Step 150 where the next most desirable system is selected from the preferred roaming list.

[0032] In a preferred embodiment, the value of the Avoidance_Duration used to calculate the Avoidance_Time is obtained from a lookup table, such as an avoidance

25 duration lookup table 200 illustrated in Fig. 5. The lookup table 200 includes an entry for each of a plurality of communications failures, such as the identified system acquisition and registration failures listed in entries 202-214, and each entry includes a corresponding Avoidance_Duration. When a system acquisition/registration attempt fails, the mobile station 2 identifies the cause of the failure and locates the

30 corresponding Avoidance_Duration in the lookup table 200. In a preferred embodiment, the cause of the failure is identified by determining the point at which the acquisition/registration procedure failed. The corresponding Avoidance_Duration

is then added to a current time to produce an Avoidance_Time for the failed system. In alternative embodiments, the Avoidance_Duration may be a predetermined constant or function that is applied to each new entry in the avoidance data 104.

[0033] The avoidance duration lookup table 200 preferably includes a record that corresponds to each system acquisition/registration failure that is detectable by the mobile station 2. For example, an attempt to acquire/register with a selected CDMA system will fail if the mobile station 2 is unable to acquire the system's pilot signal (record 202), synchronization channel (record 204) or paging channel (record 206). Even if the mobile device 2 is able to acquire the necessary signals, registration may be rejected by the selected system (record 208). In addition, attempts to access the selected system may fail due to an access denial, an access time out, maximum access probes transmitted or an unsupported channel assignment. The mobile device 2 may experience frequent signal fading (record 210) or otherwise determine that a received signal quality is inadequate. An acquisition/registration attempt may also fail if the mobile station 2 and the selected system use incompatible protocol revisions and hardware (record 212). Communications failures can also occur after the mobile station 2 acquires and registers with a selected system. For example, the mobile station 2 may receive an invalid redirection message (record 214) on a paging channel.

[0034] Having thus described a preferred embodiment of the Method and Apparatus for Efficient Selection and Acquisition of a Wireless Communications System, it should be apparent to those skilled in the art that certain advantages of the within described system have been achieved. It should also be appreciated that various modifications, adaptations, and alternative embodiments thereof may be made within the scope and spirit of the present invention. For example, it is contemplated that the mobile station 2 may override the avoidance data 104 and attempt to acquire an unusable system.

[0035] The scope of the present invention is defined by the following claims.